Charm Hadroproduction*

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These lectures cover a broad discussion of charm production in hadronic interactions. Heavy quark production beyond leading order was reviewed first. Some puzzling aspects of charm production, not described by perturbative QCD alone, were briefly touched upon. The intrinsic charm model was then introduced and some of its predictions described. We showed how the intrinsic charm probability is obtained from the charm structure function and compared the results to hadroproduction data. Only charm was discussed here but heavier quarks can be treated more reliably because the charm quark mass is small.

Theoretical work has shown that the next-to-leading order, NLO, corrections to the leading order, LO, heavy quark Born cross section can be large, especially true for charm quarks. A complete calculation of higher order corrections beyond NLO is very difficult and is so far not possible. However, near threshold large logarithms arising from an imperfect cancellation of the soft and virtual terms can be resummed to make more reliable theoretical predictions. An approximation of these contributions was used to resum the leading logarithmic (LL) terms to all orders in perturbation theory, analogous to resummation of the Drell-Yan process. The method relies on the proportionality of the higher order terms to the Born cross section. The LL resummation calculation has been improved by the inclusion of NLL terms. A significant enhancement over the LL result is seen when the NLL terms are included, particularly at small $s_4/2m_c^2$. A cutoff must be adjusted to regulate the hadronic cross section. However, since the cutoff is empirical, especially for charm, definitive statements about a resummed NLL result are difficult to make.

Thus perturbative QCD cannot fully predict the charm cross section at all orders because the charm quark is so light. The LO and NLO calculations can describe charm production over most of phase space but generally fail when the charm quark carries a large fraction of the initial longitudinal momentum, x_F. Intrinsic charm (IC), $c\overline{c}$ fluctations in the hadron wavefunction, a higher twist effect, can dominate charm production at large x_F. Since these IC fluctuations are not far off mass shell, they can be liberated by a soft interaction which breaks the coherence of the Fock state provided the system is probed while such fluctuations exist. The parton distributions reflect the underlying shape of the Fock state wavefunction.

Photon-gluon fusion explains the bulk of the charm quark contribution to the deep inelastic structure function F_2 except at large x and Q^2. A LO analysis of the data with both fusion and IC showed that IC could account for the difference between photon-gluon fusion and the data. The NLO IC corrections were then calculated and, based on LO photon-gluon fusion, the IC probability was found to be 0.3%. More recently, this analysis was revisited with a consistent NLO treatment of both photon-gluon fusion and IC, finding an IC probability of $(0.86 \pm 0.60)\%$.

The role of IC in hadroproduction is now discussed. The total x_F dependence is the sum of leading twist fusion and intrinsic charm. There are two ways of producing charm hadrons from IC states. The first is by uncorrelated fragmentation. If the projectile contains the corresponding valence quarks, the charm quark can also hadronize by coalescence with the valence spectators. The coalescence mechanism thus introduces flavor correlations between the projectile and the final-state hadrons. Including IC has resulted in good agreement with a wide range of data.

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